

Ocean: CMIP6 model evaluation needs

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Currently visiting LBNL and LLNL

- *Specific challenges in ocean model evaluation*
- *Surface fluxes*
- *Sea level height, ocean color*
- *Sea surface salinity*
- *Looking ahead*

Thanks to

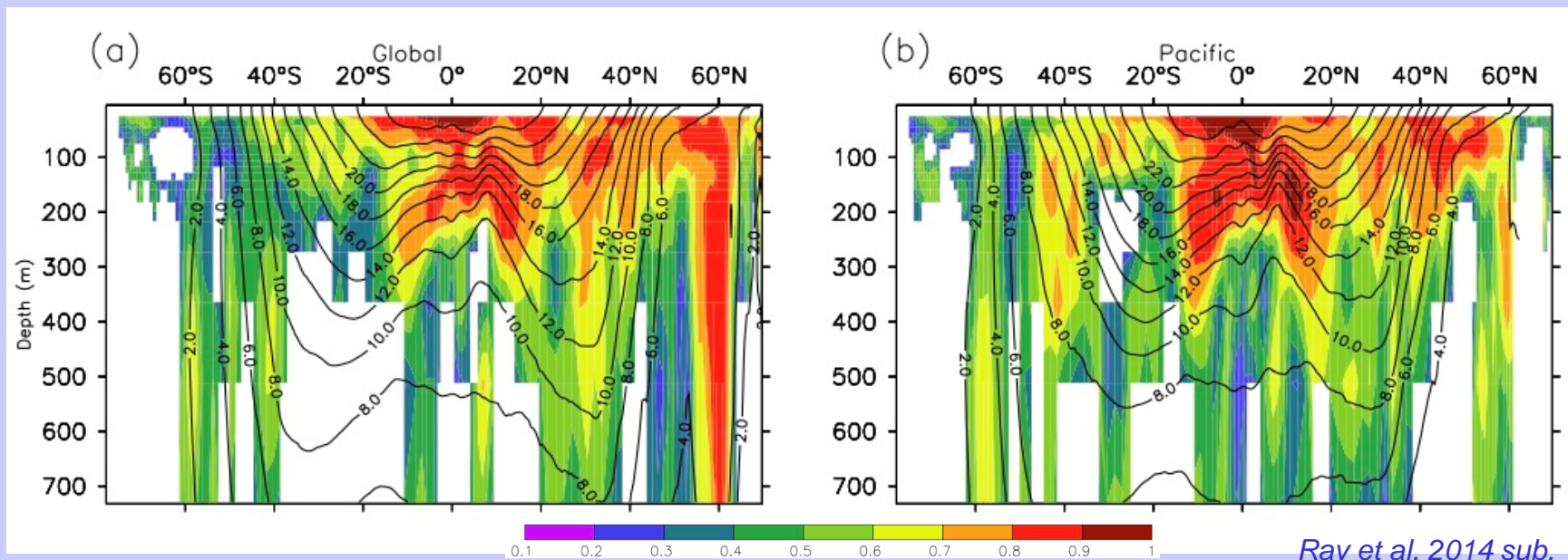
Jacqueline Boutin, Paul Durack, Peter Gleckler, Steve Griffies, Andrew Wittenberg

Obs4MIP meeting - Washington DC - April/May 2014

Specific challenges in ocean model evaluation

- *Long time scales, small spatial scales, difficult to observe*
 - *Evaluation for last 5-6 decades is a challenge (data missing)*
 - *Continuity vs. mean climate /uncertainty/biases challenge*
- *Surface vs. depth (integrated or not) different issues*
- *Ocean integrals as important as budgets/transport at choke points and key sections (ACC, ...)*
- *Observations from space:*
 - *surface and indirect sub-surface (opaque, sea level)*
 - *Complement in situ, TAO, ARGO, XBTs*
- *Coherent products (SST, turbulent/radiative fluxes,...) hold value for process understanding (e.g. TAO)*
- *OGCMs higher resolution than AGCMs*

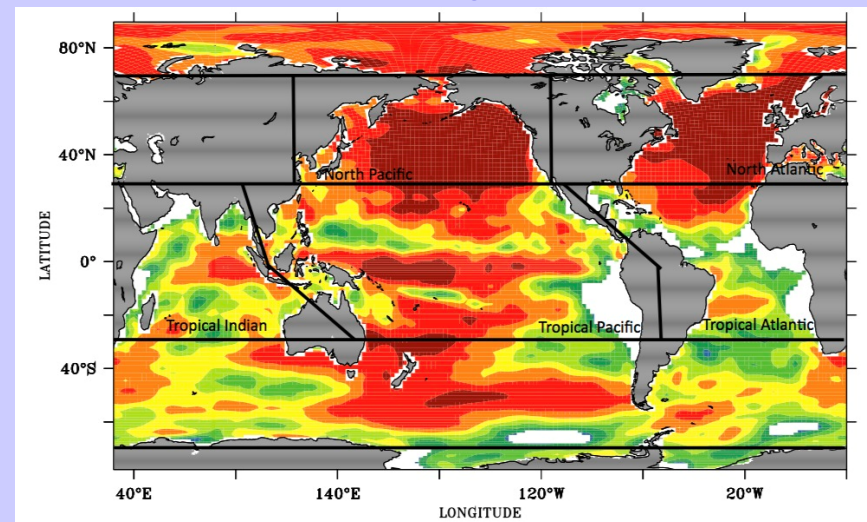
Example: where do ocean reanalysis agree ?



SODA-ORAS4 correlation 1958-2001

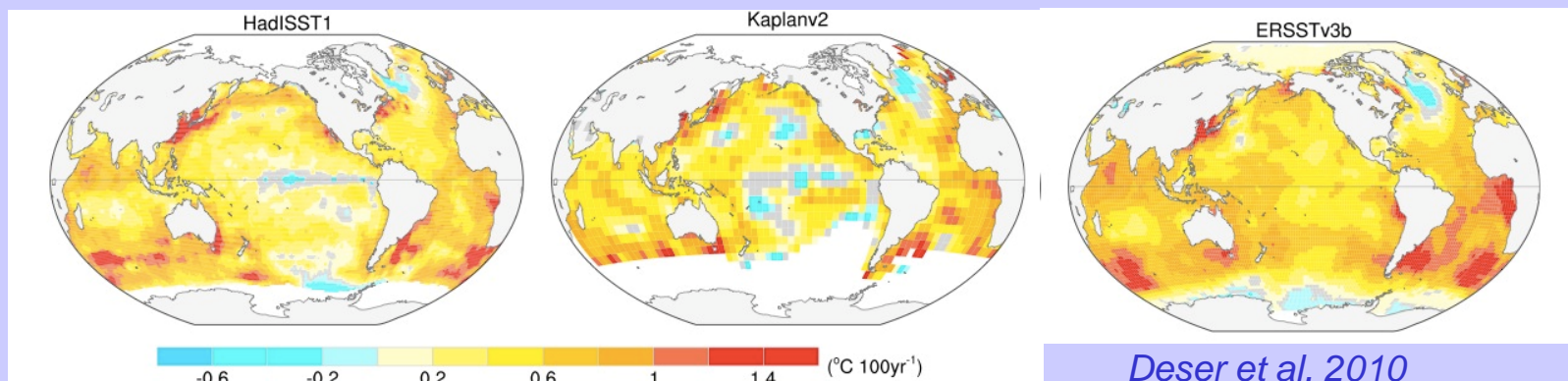
- Agree where in situ observation exist
- Forcing fields play a key role
- Cannot be used to validate models in most of the ocean

SODA-ORAS4 wind forcing correlation 1958-2001



SST

- Extensively used for coupled model evaluation
- Well observed by satellite since 1979
- Routine calibration (mostly for NWP)
- Longer “climate quality” time series via reanalysis (ERSST, HadISST, KAPLAN...)
 - agree on the larger/global scales
 - some regional discrepancies in multi-decadal trends
- Obs4mip challenges (variability and trend):
 - need to better document reanalysis differences < 1979
 - higher resolution than typical 1 deg
 - Higher time sampling (diurnal cycle, intraseasonal)
 - work with ana4MIP and data assimilation community

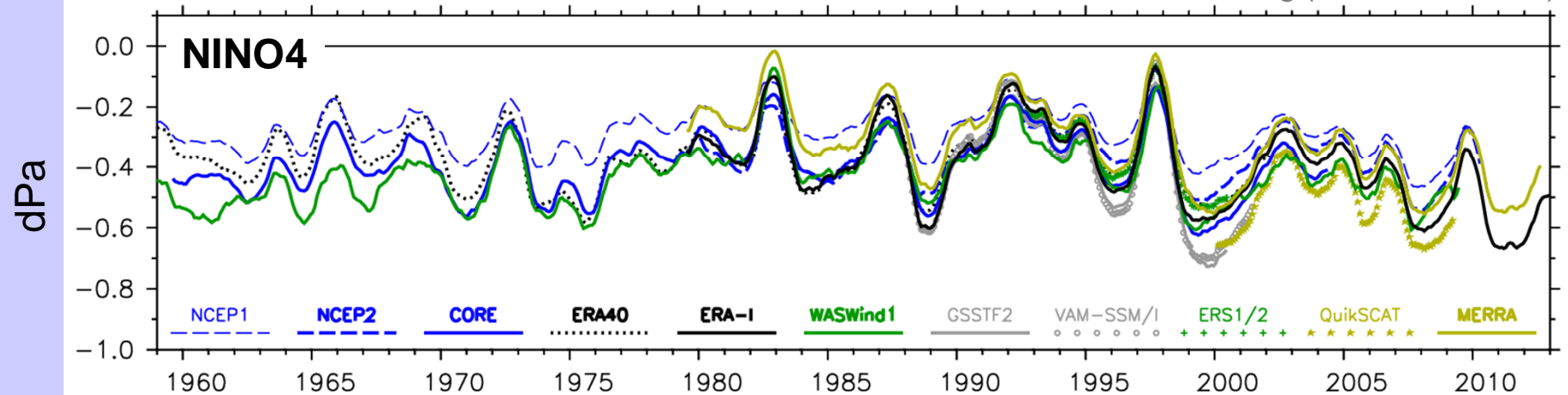


Surface fluxes

- *Key variables: drive $O(0)$ ocean circulation*
- *Observation-based estimates are hugely uncertain relative to what they need to be to help model development (long standing problem)*
- *Bulk formulae based ocean-only simulations choice approach for ocean model developers (not yet in CMIP)*
- *Splicing of different satellite data into coherent products*
- *Turbulent fluxes:*
 - *Wind stress, LH, SH*
 - *reanalysis key but must be fed/validated by satellite obs*
- *Radiative fluxes*
 - *Splicing and continuity issue*
- *Diurnal cycle and smaller scales may provide process-based evaluation (still untapped ?)*

Estimated zonal wind stresses (equatorial Pacific, running annual mean)

extended from Wittenberg (J. Climate, 2004)

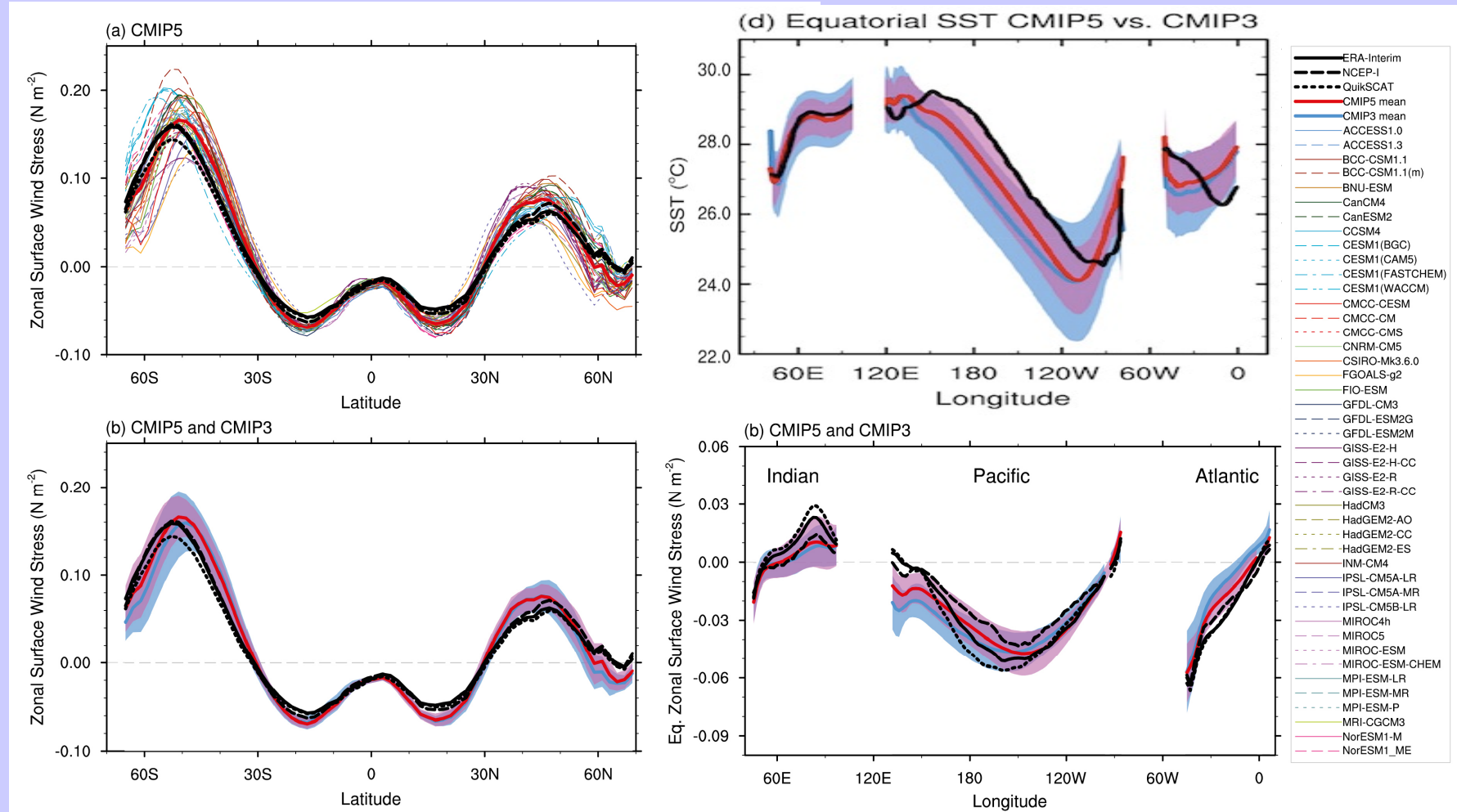


- Substantial impact on the equatorial thermocline slope, currents, and upwelling in ocean-only simulations, ocean state estimates, and ocean initializations
- Which observation for model evaluation ?
- Near-term challenges for satellite observations:
 - continuing lack of convergence among the various wind stress products
 - gaps between satellite missions (e.g. due to the loss of QSCAT)
 - the recent crisis of the TAO array, in particular near the equator, whose anemometers and thermocline measurements are critical for ground-truthing the satellite estimates

Zonal wind stress in CMIP

Zonal Mean

Along Equator



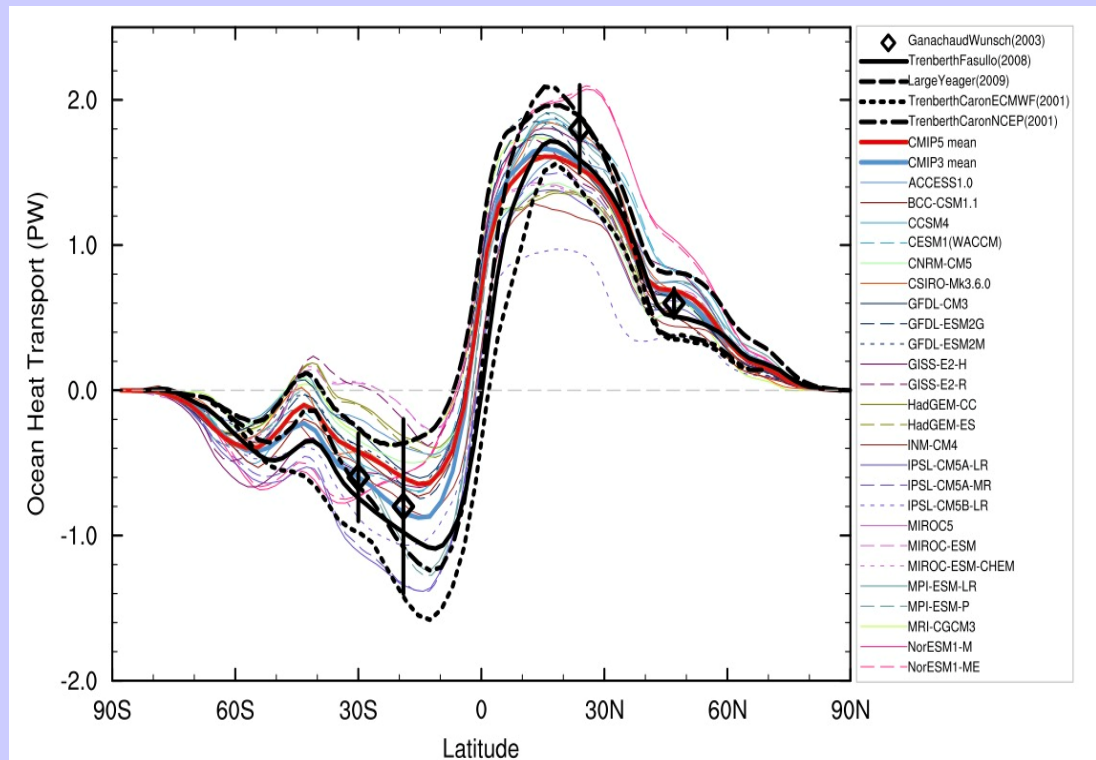
Observational constraint strong

Observational constraint weak

IPCC AR5 WG1 Figs 9.19 and 9.20

Meridional heat transport

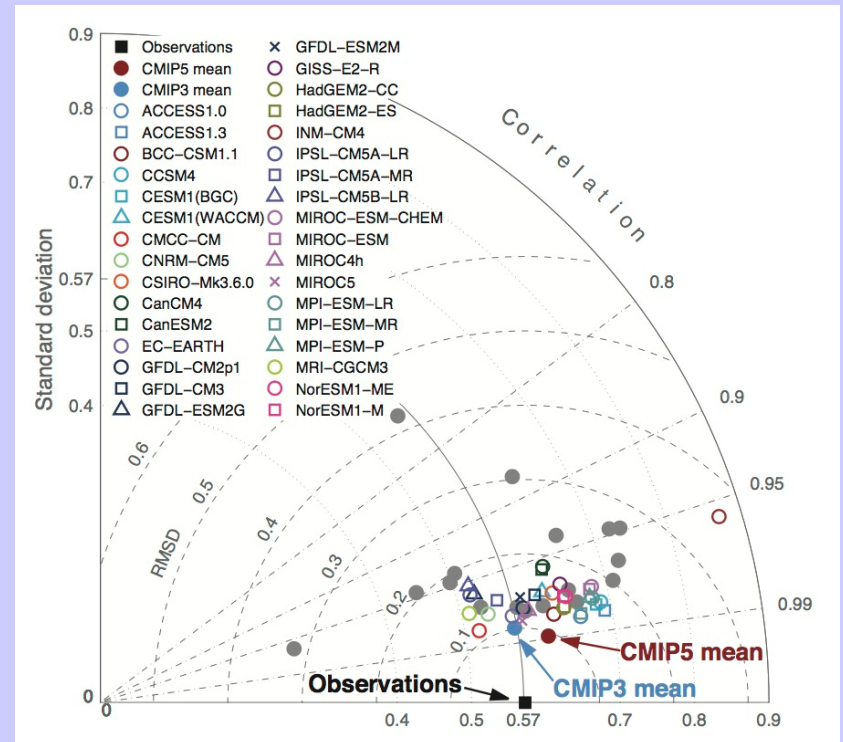
- *Key integrated variable for model evaluation*
- *Direct measurements scarce*
- *Integration of “observed” surface heat flux used as proxy*
- *Requires ad hoc corrections to account for uncertainty in measurements*



IPCC AR5 WG1 Fig 9.21

Sea level height

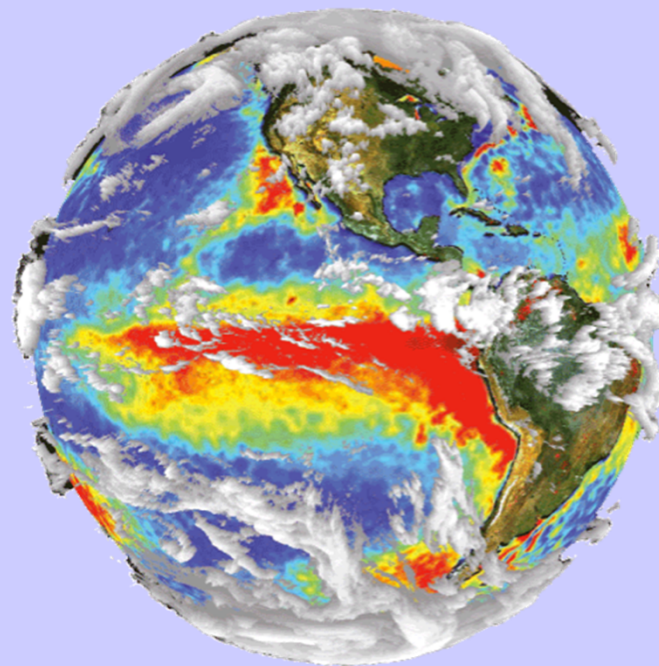
- Since 1992 and T/P, *sla* provides a depth integrated circulation product
- Largely influenced by wind stress
- Higher resolution simulations will need higher observation resolution
- AVISO is being used increasingly to evaluate eddying ocean simulations. The new AVISO product is 1/4 degree and daily, though the actual resolution is coarser (currently 1 degree in *obs4MIP*).



Taylor diagram for the dynamic sea surface height climatology (1987–2000).
Observations = AVISO
IPCC AR5 WG1 Fig 9.16

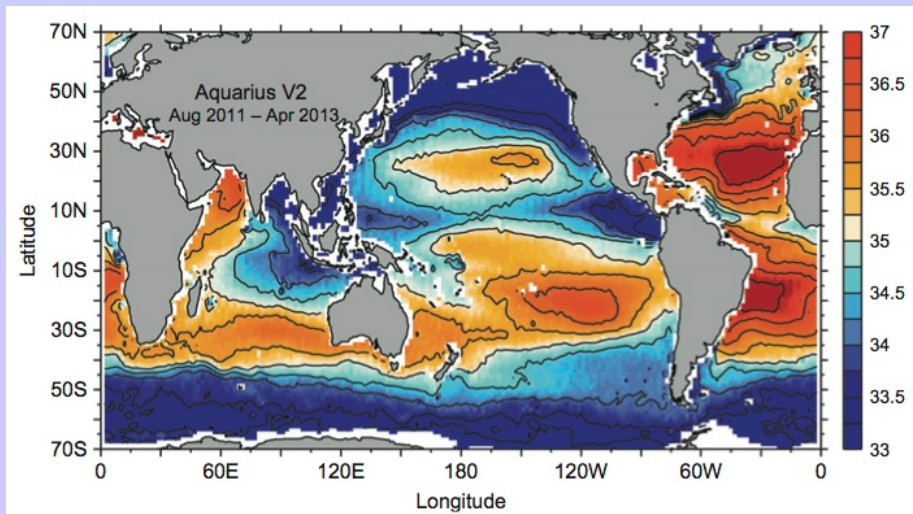
Ocean color

- *Satellite observations since 1997 (SeaWiFS, MODIS,...)*
- *Validation of biogeochemical models*
- *Used for GCM model evaluation ?*

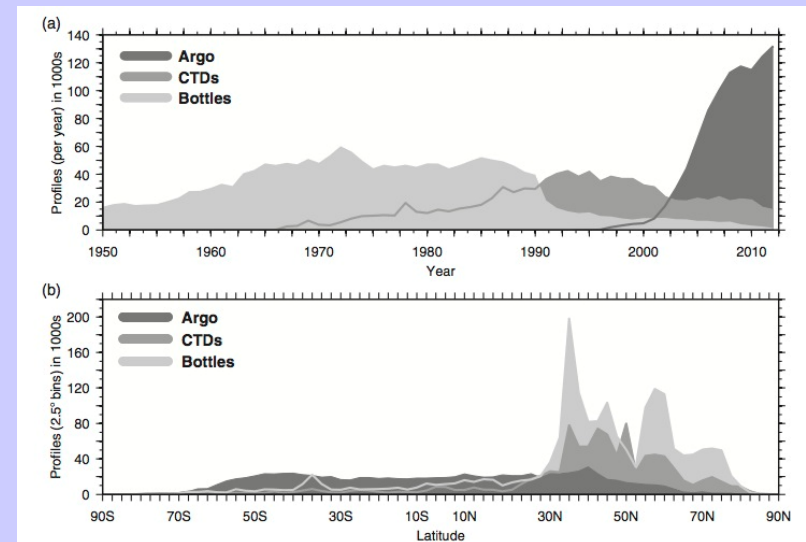


Sea surface salinity

- Satellite products since 2010 (SMOS and AQUARIUS)
- Can evaluate mean state, annual cycle, smaller scale features
- Time integrates E-P: potential to reduce obs uncertainty on E-P
- Calibration with in situ also key
- Again sustained observation is highly desirable
- Do models provide the same physical field or do we need a SSS simulator ?



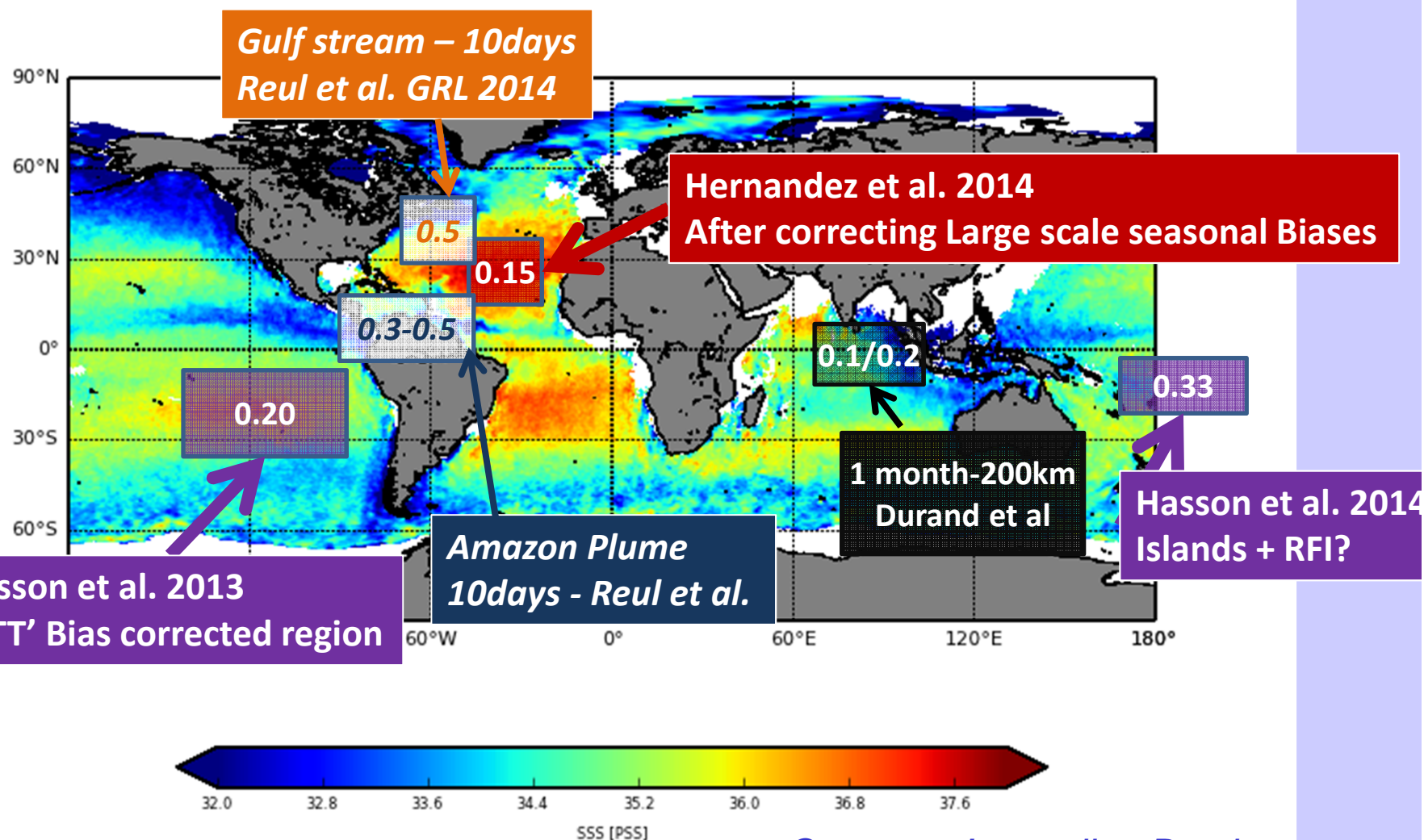
Durack et al. 2013



Density of in situ salinity profiles

SMOS SSS available since 2010

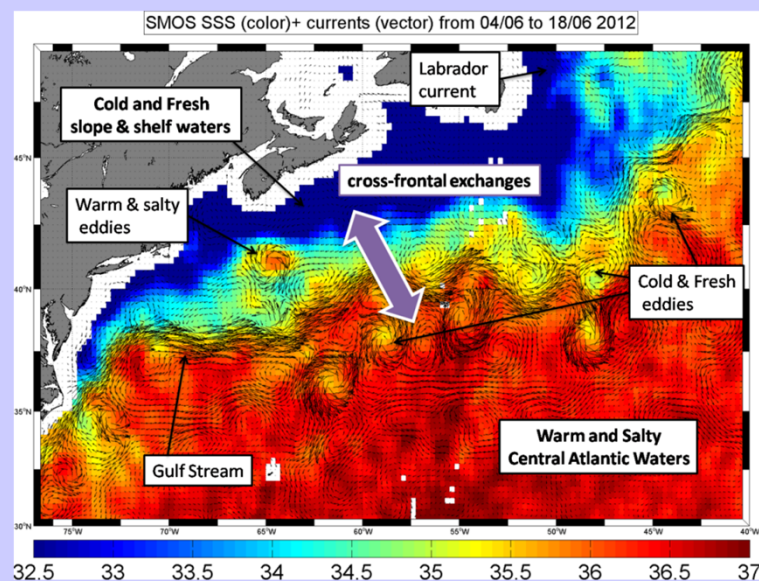
RMSDifference (SMOS SSS (**1 MONTH or 10 days**-100x100KM²) –IN SITU SSS



Courtesy Jacqueline Boutin

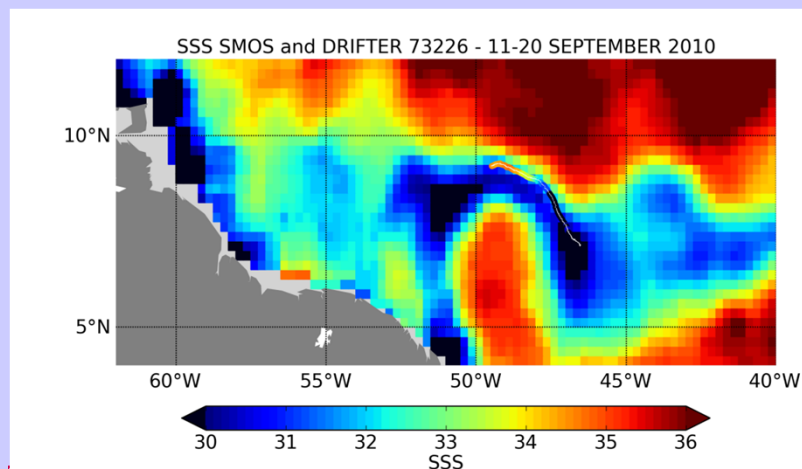
SSS for model evaluation

Gulf Stream



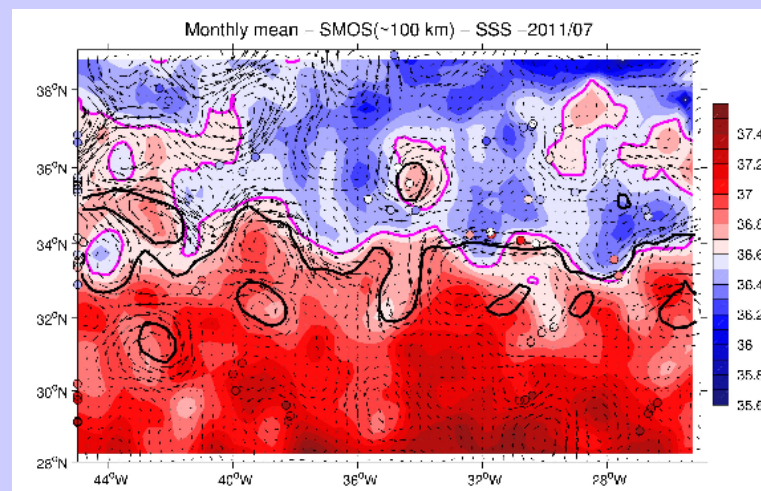
Reul et al. GRL in press 2014

Amazone plume (*Reverdin et al. 2013*)




- SMOS (2010-now) detects mesoscale variability
- precision $\sim .2$ (1month-100km), $\sim .3-.5$ (10day-100km)
- although large scale regional biases still remain to be empirically adjusted
- Not yet suited to large scale model evaluation (i.e. vs ARGO)?

Azores front/current



ps - April 2014 *Kolodziejczyk et al., 2014, in rev, JGR*

Looking ahead

- *Satellite observations for ocean model evaluation*
 1. *Coherent long time series needed*
 2. *Small scale features need to be evaluated*
 3. *Importance of in situ calibration (e.g. TAO)*
 4. *Space and time covariance of different fields**Challenge !*
- *CMIP6 Metrics (Metrics Panel and WGOMD)*
- *What are the $o(0)$ observational constraints (eg wind stress) ?*
- *Opportunities to better evaluate mean state, smaller scales (eddies, DC), ocean-atmosphere interface, transports (Drakkar validation tool)*
- *Better entrain ocean modellers in CMIP:*
 - *Few outcomes of CMIP5 comparison studies directly help the process physicist (mean state errors)*
 - *Consider intermediate configurations (e.g. nudged atmosphere simulations), include CORE3 in CMIP6*
- *Observation experts + modellers work groups (e.g. GOOS/TPOS)*

Recommendations: New requirements for TPOS 2020

Resolving the Atmosphere/Ocean interface

- Higher vertical resolution of temperature, salinity, velocity resolving the diurnal cycle across regimes
- Expand the number of locations where the full energy, water and momentum exchanges are monitored.

Boundary regions

- Define requirements for sustained observations of equatorial, eastern and western boundary regions.
- Task NPOCE, SPICE, ITF TT, Eastern Boundary regional nations/alliances to assess requirements for observations in sustained mode (e.g. Sustained array for ITF based on INSTANT)

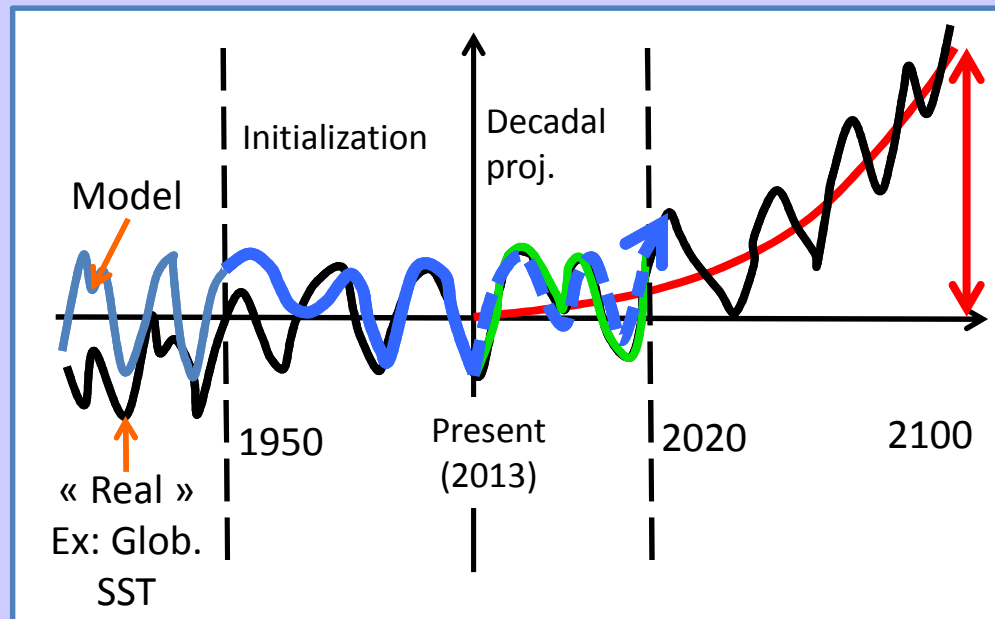
Deep Ocean

- Extend observations to the deep ocean as part of a global Deep Ocean Observing Strategy (DOOS)



Ocean model initialization

Goal is to drive the model towards the observed trajectory



Many different ways to do this as it is a difficult problem:

- Not enough quality 4D ocean observations
- Hard to distinguish internal vs. forced variability
- Model errors
- 4D var data assimilation of coupled ocean-atmosphere system not possible (yet?)